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# Laser Treatment of Accidental Tattoos: Experience at a Tertiary Referral Center

Corinne D.C. Eggenschwiler Reinhard Dummer Laurence Imhof

Department of Dermatology, University Hospital of Zurich, Zurich, Switzerland

**Keywords**
Dermatologic surgery · Laser treatment · Surgical techniques · Tattoo pigment

**Abstract**
***Background:*** To date, information on laser treatment of accidental tattoos is limited. ***Objectives:*** This study analyzes the efficacy and safety of quality-switched ruby, quality-switched Nd:YAG and picosecond lasers in the treatment of accidental hyperpigmentation in a larger patient cohort. To date, there is limited information on laser therapy of accidental hyperpigmentation. ***Methods:*** We conducted a retrospective systematic single-center analysis on 70 patients, which presented with accidental hyperpigmentation at the Dermatology Department of the University Hospital of Zurich between 2008 and 2017. Patients with accidental tattoos due to road injuries, explosives or other traumas and iatrogenic measures were included. We analyzed the data including laser parameters such as wavelength, energy density, spot size and intervals between the sessions. Also, the number of sessions performed and the overall success were registered. ***Results:*** We treated 38 patients by quality-switched nano- and/or picosecond laser therapy and completed the treatment in 28 cases within a mean number of 3–5 laser sessions. No complications occurred. ***Conclusion:*** We demonstrate the validity and safety of quality-switched and picosecond lasers in the treatment of accidental hyperpigmentation. Using a combination of different wavelengths and pulse lengths on the same lesion and gradually increasing the fluence in the course of the laser treatment is recommendable to increase efficacy. We observed a tendency towards faster elimination of facial accidental tattoos and/or originating from road injuries compared to tattoos located on the extremities and those caused by explosions, piercings or iatrogenic measures or consisting of metal pigment particles.


## Introduction

Accidental tattoos are caused by a persisting deposition of exogenous pigment particles like metal salts or carbon in the dermal or subcutaneous section of the skin. The most common causes are traumatic (abrasive or explosive injuries, such as road accidents and firework explosions), iatrogenic (paravasal injections, intracutaneous sutures or joint prostheses) [1–5] and from chronic intake of drugs such as certain antibiotics or antimalarials [5, 6]. They are frequently a cosmetic burden to the patient and require therapy. The topical application of skin-lightening creams containing retinoids or hydroquinone shows no efficacy [7]. Surgical procedures such as exci-

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Dr. Laurence Imhof
Director of Physical Therapies and Aesthetic Dermatology
Department of Dermatology, University Hospital of Zurich
Gloriastrasse 31, CH–8091 Zurich (Switzerland)
laurence.imhof@usz.ch

sion of larger particles, skin debridement, superficial dermabrasion or deeper chemical peelings are viable options to remove the unwanted pigment. However, all of these procedures are painful, carry a significant risk for further scarring and usually fail to ensure a complete eradication of the exogenous particles [2, 8].

On the other hand, laser therapy is able to remove the disturbing hyperpigmentation due to the principle of selective photothermolysis gently and without scarring [8–11]. Thus, it represents the first choice of treatment for accidental tattoos [5, 12–16]. The quality-switched (QS) nanosecond and picosecond alexandrite (755 nm), the QS Nd:YAG (1,064 nm) and the QS ruby laser (694 nm) present the most popular devices for hyperpigmented lesions. QS lasers work with a 5- to 100-ns pulse length and a 532- to 1,064-nm light spectrum [4, 17]. The quality switch reduces the pulse duration and maximizes the released energy in a short amount of time [18]. Computers simulating the effect of the picosecond laser demonstrate that a pulse length of only a few picoseconds leads to better cosmetic results and fewer side effects than nanosecond lasers [19]. Due to the shorter pulses, efficacy is maintained despite using a lower fluence [20].

As accidental tattoos are mostly of darker colors such as blue, gray, brown or black, the absorption spectrum of the target chromophores includes the wavelengths of the lasers mentioned above (694, 755 and 1,064 nm). In practice, other factors such as the patient's skin phototype, the nature of the deposed exogenous particles as well as their depth in the tissue determine which laser device is preferred.

To date, studies on laser therapy and accidental tattoos include small patient cohorts and few Western patients. Our goal was to demonstrate the efficacy and safety of QS nanosecond and picosecond lasers for the removal of accidental tattoos of different origin in patients of all skin phototypes.

## Patients and Methods

For further details, see the online supplementary material (see www.karger.com/doi/10.1159/000506459 for all online suppl. material) (Fig. 1).

## Results

We registered 70 patients with accidental hyperpigmentation with their personal data and the laser parameters used. 54 females (77.1%) and 16 males (22.9%) were included in the analysis. Their age at first consultation ranged from 14 to 87 years. 38 patients (54.3%) were of Fitzpatrick skin phototype I or II, 22 patients (31.4%) of skin phototype III or IV, 2 patients (2.8%) of skin phototype V or VI and for 8 patients, data were missing.

We stratified the accidental tattoos according to the causative trauma, namely iatrogenic ($n$ = 32; 45.7%), road injuries ($n$ = 19; 27.1%), explosions ($n$ = 5; 7.1%), piercings ($n$ = 5; 7.1%) and other ($n$ = 9; 12.9%). Iatrogenic tattoos comprised drug-induced hyperpigmentations and paravenously administered iron injections. The tattoos were mostly located on the extremities ($n$ = 36, 51.4%) or in the facial area ($n$ = 29, 41.4%). 5 patients (7.1%) had hyperpigmentations on multiple or other sites of the skin. The lesions were of brown ($n$ = 32; 45.7%), gray ($n$ = 18; 25.7%), blue ($n$ = 16; 22.9%), black ($n$ = 1; 1.4%), purple ($n$ = 1; 1.4%) or reddish ($n$ = 1; 1.4%) appearance. One lesion was never photographically documented and therefore not evaluated regarding its color. We biopsied 11 patients to examine the nature of the exogenous pigment more closely, but a large part of analyzed tattoos contained exogenous pigment that was not definitely identified. The pigment was then classified based on the patient history. The largest part of the accidental tattoos contained metal ($n$ = 37; 52.9%), followed by tattoos most likely consisting of asphalt or gravel ($n$ = 19; 27.1%). In 6 cases (8.6%), the origin of the pigment remained unknown. 3 tattoos (4.3%) were drug-induced, 3 (4.3%) consisted of gunpowder particles and 2 (2.9%) of black rubber.

*Course of Therapy*

38 patients (54.3%) underwent laser therapy to remove their accidental hyperpigmentations. In 28 patients (40.0%), the treatment was completed, in 7 patients (10.0%), treatment was still ongoing at the time of the analysis, and 3 patients (4.3%) did not pursue the laser sessions until complete removal. 2 patients (2.9%) had the lesion removed by dermabrasion or excision, and 30 patients (42.9%) did not start laser treatment due to personal or financial reasons.

The patients received treatment with the QS ruby 694-nm laser, the QS Nd:YAG 1,064-nm laser, the picosecond 660/1,064-nm laser or with a combination of these. The QS ruby laser was implemented in 28 out of 38 patients, whereas the QS Nd:YAG device was used in 25 patients. We only rarely implemented the picosecond model ($n$ = 7) as this laser was not present in the clinic until the last few months of the observed time period. We used the 1,064-nm ($n$ = 7) or the 660-nm wavelength ($n$ = 1) of the

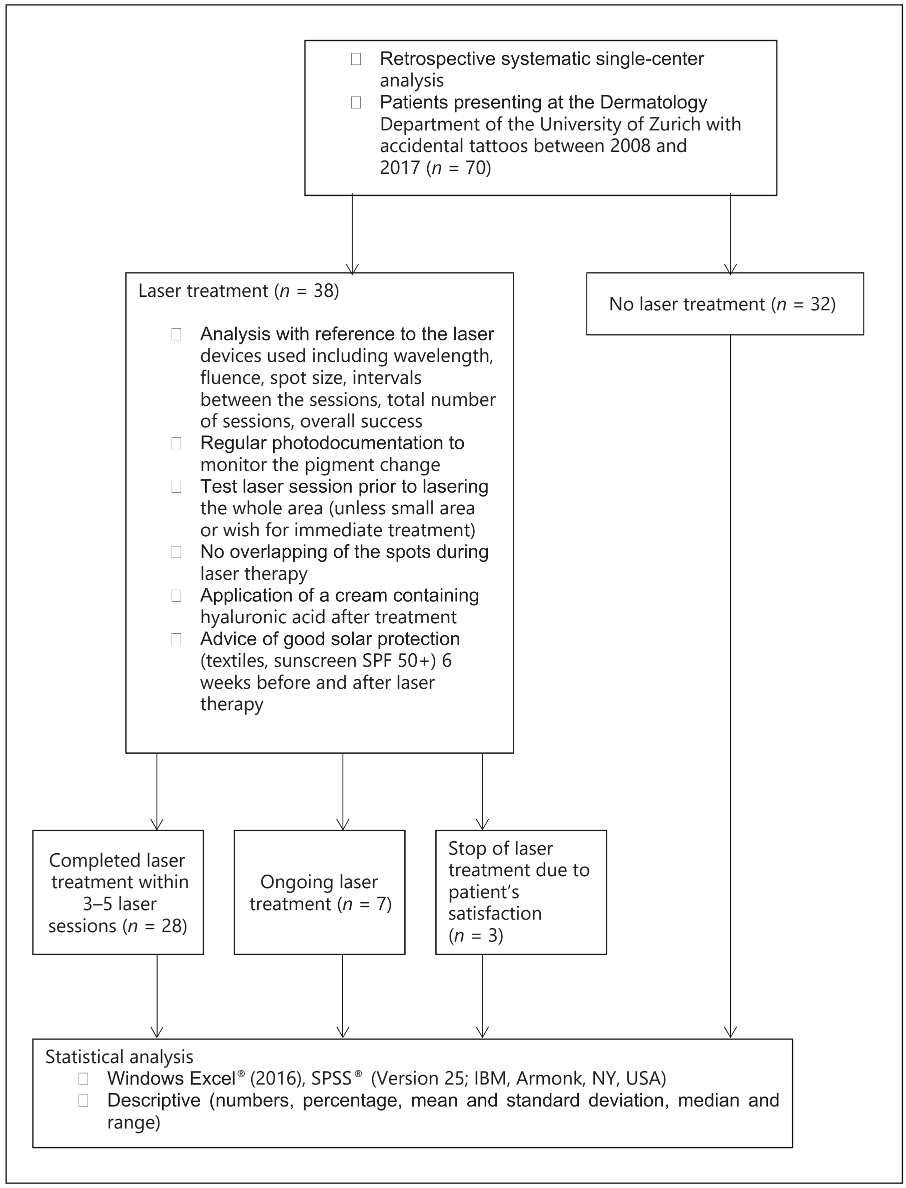


**Fig. 1.** Flowchart of the Patients and Methods.

picosecond laser. Most patients received treatments with more than one model.

The individual wavelengths differ not only in their absorption capacity, but also in their penetration depth. Alexandrite and ruby lasers are very similar in their behavior and are characterized by a stronger absorption with darker brown to black pigment particles. Due to the protection of the epidermal pigment with increasing wavelength, we preferred to use the Nd:YAG 1,064-nm laser for darker skin types. The combination of wavelengths during the course of the treatment was carried out with the aim of reaching the foreign particles at different levels of the skin. Picosecond lasers were preferably used towards the end of the treatment process since after several pretreatments, shrinkage of the particle size can be assumed. In correlation, the pulse duration should theoretically also become shorter.

The median time between the development of the tattoo and the start of the laser treatment was 0.9 years (0.1–22 years). The energy density (J/cm$^2$) we used varied depending on the laser device, the wavelength and the amount of exogenous pigment. A detailed description of the energy density used is shown below (Table 1). The spot size ranged from 3 to 6 mm in diameter. We performed the laser sessions in intervals ranging from 2 weeks to 2 years.

**Table 1.** Energy densities used on the laser devices in the treatment of the accidental tattoos ($n$ = 38)

| | Patients, $n$ | Mean energy density ± standard deviation, J/cm$^2$ |
|---|---|---|
| QS ruby laser (694 nm) | 28 | 3.32±0.848 |
| QS Nd:YAG laser (1,064 nm) | 25 | 4.78±2.221 |
| Picosecond laser (1,064 nm) | 7 | 2.29±0.603 |
| Picosecond laser (660 nm) | 1 | 1.10 |

QS, quality-switched.

**Table 2.** Patients with accidental hyperpigmentations treated successfully via laser therapy: stratification into clinical groups according to their causative trauma ($n$ = 28)

| Causative trauma | Mean number of laser lessions | Range of number of laser sessions |
|---|---|---|
| Iatrogenic ($n$ = 7) | 5.1 | 4–9 |
| Road injuries ($n$ = 12) | 3.1 | 1–7 |
| Explosive trauma ($n$ = 2) | 4 | 2–6 |
| Piercings ($n$ = 4) | 4.5 | 1–11 |
| Other ($n$ = 3) | 3.7 | 2–5 |

*Side Effects of Laser Therapy*

Short-term side effects after laser therapy include redness, pain and swelling, which were only present in the first few days after therapy. Some patients additionally reported crusting ($n$ = 9; 23.7%), blistering ($n$ = 7; 18.4%) and punctual bleeding ($n$ = 3; 7.9%). No severe long-term side effects such as scarring occurred. 2 patients developed a slight hyperpigmentation on the lasered area. Both of them were of darker skin phototypes (IV and V). One of them (skin phototype V) showed a temporary hyperpigmentation 3 weeks after a probatory laser session with a QS Nd:YAG laser, which turned into lightening of the lasered area at the second follow-up consultation 14 weeks after the test laser treatment. The other patient (skin phototype IV) developed focal hyperpigmentation after treating a test spot with the QS ruby laser, which currently (5 years after completion of laser therapy) persists.

In 6 out of 38 lasered patients (16.2%), all of whom belonged to the group of iatrogenic accidental tattoos, slight focal hypopigmentation occurred as a longer-lasting side effect after successful termination of laser therapy. In all of these cases, the QS ruby laser was either used as the sole model ($n$ = 2) or in combination with other lasers ($n$ = 4). The hypopigmentation completely resolved in 3 out of the 6 affected patients within 4 years after completion of laser therapy. In 1 patient, the dyspigmentation is currently (8 years after completion of therapy) still present but only recognizable in a tanned state. The remaining 2 patients were lost to follow-up.

*Completed Laser Therapy*

In 28 cases (40.0%), we pursued laser therapy until we achieved complete disappearance of the accidental hyperpigmentation or patients' satisfaction. We treated all patients with the QS ruby laser (694 nm), the QS Nd:YAG laser (1,064 nm), the picosecond laser (660 or 1,064 nm) or with a combination of these, according to the considerations described above. We additionally used a $CO_2$ fractional laser in some cases to treat the scar that sometimes accompanied the tattoo, the analysis of which is not part of the goal of this study. Table 2 shows the mean number as well as the range of the number of laser sessions needed for a successful completion of treatment with stratification into different clinical groups according to the causative trauma.

## Discussion

To our knowledge, this is the first analysis of accidental tattoos and their removal via QS nanosecond and picosecond lasers in a large cohort of patients. Analyzing 38 cases, we demonstrate the efficacy of the QS ruby, the QS Nd:YAG and the picosecond laser in the removal of accidental hyperpigmentations of different causes and in different localizations of the body. We achieved a removal within a mean number of 3–5 sessions using an energy density between 1.10 and 4.78 J/cm$^2$. We observed a faster removal in tattoos due to road injuries (3 sessions) compared to tattoos caused by iatrogenic measures (5 sessions).

In the 38 cases, we used the QS ruby, the QS Nd:YAG or the picosecond laser, which all present valid devices when used alone or in combination. The darker skin types were preferably treated with the Nd:YAG 1,064-nm laser because of the protection of the epidermal pigment. Wavelength combinations were used to achieve different depths of pigment particles. Picosecond lasers were used for assumed smaller pigment particles. Due to the non-controlled use of the lasers and the limited number of patients, no laser showed significant superiority regarding the number of sessions or the side effects. We could not detect any correlation between the choice of the laser device and the causative trauma or the material of the accidental hyperpigmentation.

We set the fluence (J/cm$^2$) depending on the clinically visible amount of the exogenous pigment, the patients' skin phototype and the reaction of the tissue after a probatory laser shot. Slight whitening and a minor but audible bang were the intended immediate reaction. When we clinically observed a gradual reduction in pigment in the course of the treatment, we increased the fluence. It is common that the laser device starts showing reduced efficacy in lightening up the lesion after several treatments [21]. This is partly attributed to the distribution of the exogenous pigment in different layers of the skin, not all of which are targeted by one specific wavelength. Hence, using different wavelengths may lead to the best possible result [22]. Moreover, we recommend shorter pulse durations in the course of the treatment as the particles gradually become smaller and consequently require less time to reach the temperature needed for their fragmentation [23]. The fluence used in our cohort was lower when using the picosecond laser (1.10–2.29 J/cm$^2$) than with the QS lasers (3.32–4.78 J/cm$^2$). We attribute this to the emission of shorter pulses in the picosecond device, which allows more efficient heat generation despite a reduction in fluence [20].

We observed a tendency towards a faster removal of accidental tattoos caused by road injuries, when asphalt or gravel were involved, compared to explosive trauma, piercings and iatrogenic tattoos, which is in concordance with previously conducted research [24], according to which gravel tattoos were removed faster than tattoos due to explosions. Removal of softer pigment particles is easier than harder material such as metal [16, 18]. A tendency towards a faster removal of tattoos caused by asphalt in comparison with metal was seen in our analysis.

Iatrogenic hyperpigmentation showed the highest number of laser sessions needed among all evaluated groups. We partly attribute this to the assumable deposition of the pigment particles in deeper layers of the skin compared to explosions or abrasive injuries. Another contributing factor may be the localization on the more distal parts of the upper extremities, where the lymphatic transport system is not as extensive as in the head and neck area [25, 26]. We saw a trend towards a faster removal of tattoos in the facial area, where the efficacy of pigment transport is considered higher, compared to tattoos on the extremities.

Patients with Fitzpatrick skin phototypes IV–VI are more prone to acute or chronic complications after laser therapy than fairer skin phototypes due to the presence of more melanin pigment [27]. Especially the wavelengths of the QS alexandrite and ruby lasers (755 and 694 nm) lead to a high absorption not only of the targeted chromophore, but also of the organic epidermal melanin pigment, which is why hypopigmentation after laser therapy is a well-known side effect. Therefore, a longer wavelength such as 1,064 nm is the first choice in darker skin as these rays penetrate more deeply into the tissue and reduce the effect on the superficial melanin [28–30].

Tattoos in darker skin phototypes are associated with more laser sessions due to the more conservative setting of the fluence because of the higher risk for complications [25]. In our analysis, too few patients with skin phototypes IV–VI were included to make a valid statement.

The strength of this paper is the high number of patients included in the analysis. To our knowledge, no publication with more than 32 patients [30] with accidental tattoos and laser therapy exists, and then using only one laser device and including merely Asian patients [30, 31]. We treated most patients with more than one wavelength (1,064, 694, 660 nm) due to individual differences such as skin phototype and characteristics of the tattoos. Additionally, we made continuous adjustments regarding wavelength and fluence depending on the observed lightening reaction after every laser session.

Due to the heterogeneity of the tattoos in our cohort regarding clinical aspect, material, extent, amount and depth of exogenous pigment particles as well as the patients' skin phototype, we could not assess a significant correlation between the localization or the material and the number of sessions needed. However, we demonstrate an adequate setting of the laser parameters that leads to an efficient and safe removal of the accidental hyperpigmentation with an excellent cosmetic outcome. Together with influence factors such as the localization of the tattoos as well as the amount, depth and nature of the exogenous pigment, they determine the number of laser sessions needed. No long-term severe complications such as scarring after laser therapy occurred. Mild side effects included short-term redness, swelling, minor pain as well as less frequently punctual bleeding, blisters, crusting, focal hypopigmentation or hyperpigmentation on the lasered area.

Leuenberger et al. [32] compared all three QS lasers in the treatment of black and blue tattoos, with the QS ruby laser presenting with the highest prevalence of hypopigmentation. In our analysis, the 6 patients who showed slight focal hypopigmentation after laser treatment were all treated with the QS ruby laser at least once. 5 patients were of skin phototype II or III, and one patient showed


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skin phototype IV. We can therefore not confirm a higher incidence of focal hypopigmentation in people with skin phototype IV–VI, as it is stated in the literature [20].

We observed hyperpigmentation after laser therapy in 2 patients, who were of skin phototypes IV and V. Hyperpigmentation after laser therapy has a higher incidence in patients with darker skin phototypes (IV–VI) but usually resolves within weeks or months [20]. This was the case in 1 of our 2 patients.

In conclusion, we show safe and efficient elimination of accidental hyperpigmentation with QS nano- and picosecond lasers within a mean number of 3–5 sessions. We suggest using a combination of different wavelengths and pulse lengths on the same lesion to achieve optimal results, and gradually increase the fluence in the course of the laser treatment. We observed a tendency towards faster elimination of facial accidental tattoos and/or originating from road injuries compared to tattoos located on the extremities and those caused by explosions, piercings or iatrogenic measures or consisting of metal pigment particles. Due to the heterogeneous cohort in terms of skin phototype, material, depth and amount of exogenous pigment, it is difficult to determine standardized laser parameters and to show significant differences between the used laser devices.

## Key Message

Laser treatment with quality-switched nano- and picosecond lasers is the first choice to safely eliminate accidental tattoos.


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## Statement of Ethics

This study meets the requirements of the law on human research and has been authorized by the responsible ethics committee (project ID: 2017-01966).

## Disclosure Statement

The authors declare no conflicts of interest. Prof. Dummer has intermittent, project-focused consulting and/or advisory relationships with Novartis, Merck Sharp & Dohme, Bristol-Myers Squibb, Roche, Amgen, Takeda, Pierre Fabre and Sun Pharma outside the submitted work.


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## Author Contributions

R.D., L.I., C.D.C.E.: study design, data collection. L.I., C.D.C.E.: patient interviews, writing of the manuscript, statistical analysis with the data collected.

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